PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B26B 21/54, C23C 14/32 | A1 | (11) International Publication Number: WO 93/00204

(43) International Publication Date: 7 January 1993 (07.01.93)

(21) International Application Number: PCT/US92/04932

(22) International Filing Date: 11 June 1992 (11.06.92)

(30) Priority data:
719,793 24 June 1991 (24.06.91) US
792,427 15 November 1991 (15.11.91) US

(71) Applicant: THE GILLETTE COMPANY [US/US]; Prudential Tower Building, Boston, MA 02199 (US).

(72) Inventors: PARENT, C., Robert ; 69 Hawthorne Street, Westwood, MA 02090 (US). MADEIRA, John ; 5 Amanda Road, Assonet, MA 02702 (US). HAHN, Steve, Syng-Hi ; 7 Trinity Court, Wellesley Hills, MA 02181 (US). CHOU, Chong-Ping, Peter ; 8 Carol Lane, Lexington, MA 02173 (US). BROOKS, Lamar, Eugene ; 57 Temple Road, Wellesley, MA 02181 (US).

(74) Agents: GALLOWAY, Peter, D. et al.; Ladas & Parry, 26 West 61 Street, New York, NY 10023 (US).

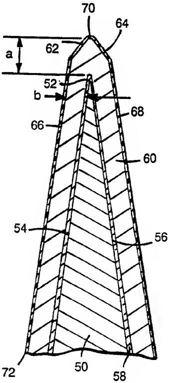
(81) Designated States: AT, AU, BB, BG, BR, CA, CH, CS, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, PL, RO, RU, SD, SE, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IT, LU, MC, NL, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG).

Published
With international search report.

(54) Title: IMPROVEMENTS IN OR RELATING TO RAZOR BLADES

(57) Abstract

A razor blade includes a substrate (50) with a wedge-shaped edge at a distance of forty micrometers from the sharpened tip (52), and a layer of diamond or diamond-like material (60) defined by facets (66, 68) that have an included angle of less than seventeen degrees that has a thickness of at least twelve hundred angstroms from the sharpened tip (52) of said substrate (50) to a distance of forty micrometer from the sharpened tip (52), and an ultimate tip defined by facets (62, 64) that have lengths of at least about 0.1 micrometer and define an included angle of at least sixty degrees, and that defines a tip radius of less than about 400 angstroms, an aspect ratio in the range of 1:1-3:1, a hardness of at least thirteen gigapascals and an L5 wet wool felt cutter force of less than 0.8 kilogram.



IMPROVEMENTS IN OR RELATING TO RAZOR BLADES

This invention relates to improved razors and razor blades and to processes for producing razor blades or similar cutting tools with sharp and durable cutting edges. A razor blade typically is formed of a suitable substrate material such as metal or ceramic and an edge is formed with wedge-shape configuration with an ultimate edge or tip that has a radius of less than about 1,000 angstroms. During use, a razor blade is held in the razor at an angle of approximately 25°, and with the wedge-shaped edge in contact with the skin, it is moved over the face so that when the edge encounters a beard hair, it enters and severs it by progressive penetration, aided by a wedging action. It is believed that the cut portion of the hair (which on average is about 100 micrometers in diameter) remains pressed in contact with the blade facets remote from the facial skin surface for a penetration up to only about half the hair diameter. Beyond this, the hair can bend and contract away from the blade to relieve the wedging forces. The resistance to penetration through reaction between hair and blade facets therefore occurs only over about the first sixty micrometers of the blade tip back from the edge and the geometry of the blade tip in this region is regarded as being the most important from the cutting point of view.

It is believed that a reduction in the

included angle of the facets would correspondingly reduce the resistance to continued penetration of the blade tip into the hair. However, when the included angle is reduced too much, the strength of the blade tip is inadequate to withstand the resultant bending forces on the edge during the cutting process and the tip deforms plastically (or fractures in a brittle fashion, dependent on the mechanical properties of the material from which it is made) and so sustains permanent damage, which impairs its subsequent cutting performance, i.e. the edge becomes "blunt" or "dull". As shaving action is severe and blade edge damage frequently results, and to enhance shavability, the use of one or more layers of supplemental coating material has been proposed for shave facilitation, and/or to increase the hardness, strength and/or corrosion resistance of the shaving edge. A number of such coating materials have been proposed, such as polymeric materials, metals and alloys, as well as other materials including diamond and diamond-like carbon (DLC) material. Diamond and diamond-like carbon (DLC) materials may be characterized as having substantial sp3 carbon bonding; a mass density greater than 1.5 grams/cm^3; and a Raman peak at about 1331 cm^{-1} (diamond) or about 1550 cm^{-1} (DLC). Each such layer or layers of supplemental material desirably provides characteristics such as improved shavability, improved hardness, edge strength and/or corrosion resistance while not adversely affecting the geometry and cutting effectiveness of the shaving edge.

In accordance with one aspect of the invention, there is provided a razor blade comprising a substrate with a wedge-shaped edge with a sharpened tip and an included facet angle in the range of 10°-17° in the region from forty to one hundred micrometers from the substrate tip, and a layer of

strengthening material on the wedge-shaped edge that is preferably at least twice as hard as the underlying substrate, and has a thickness of at least about twelve hundred angstroms from the tip of the substrate to a distance of forty micrometers from the substrate tip, defines a tip of radius of less than about 400 angstroms and that is defined by tip facets with an included angle of at least 60°, and has an aspect ratio in the range of 1:1-3:1. The blade exhibits excellent shaving properties and long shaving life.

In particular embodiments, the razor blade substrate is steel; the wedge-shaped edge is formed by a sequence of mechanical abrading steps; a layer of diamond-like carbon material is formed by sputtering material from a target of high purity graphite concurrently with the application of an RF bias to the steel substrate, the DLC layer has a hardness of at least thirteen gigapascals; and the blade edge has excellent edge strength as evidenced by an L5 wet wool felt cutter force of less than 0.8 kilogram, and negligible dry wool felt cutter edge damage (less than fifty small damage regions (each such small damage region being of less than twenty micrometer dimension and less than ten micrometer depth) and no damage regions of larger dimension or depth) as microscopically assessed.

In accordance with another aspect of the invention, there is provided a process for forming a razor blade that includes the steps of providing a substrate, forming on an edge of the substrate a wedge-shaped sharpened edge that has an included angle of less than thirty degrees and a tip radius (i.e. the estimated radius of the larger circle that may be positioned within the ultimate tip of the edge when such ultimate tip is viewed under a scanning electron microscope at magnifications of at least

25,000) of less than twelve hundred angstroms; and depositing a layer of strengthening material on the wedge-shaped edge of the substrate while an RF bias is applied to the substrate to provide an aspect ratio in the range of 1:1 - 3:1, and a radius at the ultimate tip of the strengthening material of less than about five hundred angstroms.

In a particular process, the substrate is mechanically abraded in a sequence of honing steps to form the sharpened edge; layers of an interlayer material and diamond or diamond-like material are successively deposited by sputtering; the layer of interlayer material having a thickness of less than about five hundred angstroms, and the diamond or DLC coating having a thickness of at least about twelve hundred angstroms with an ultimate tip that is defined by tip facets with an included angle of at least 60°; the layer of diamond having a Raman peak at about 1331 cm^{-1} and the layer of diamond-like carbon (DLC) material having a Raman peak at about 1550 cm^{-1}; substantial sp3 carbon bonding; and a mass density greater than 1.5 $grams/cm^3$; and an adherent polymer coating is applied on the diamond or DLC coated cutting edge.

In accordance with another aspect of the invention, there is provided a shaving unit that comprises blade support structure that has external surfaces for engaging user skin ahead and rearwardly of the blade edge or edges and at least one blade member secured to the support structure. The razor blade structure secured to the support structure includes a substrate with a wedge-shaped cutting edge defined by facets that have an included angle of less than seventeen degrees at a distance of forty micrometers from the sharpened tip, and a layer of strengthening material on the wedge-shaped cutting edge that has a thickness of at least twelve hundred

angstroms from the sharpened tip of the substrate to a distance of forty micrometers from the sharpened tip, and an ultimate tip defined by facets that have lengths of at least about 0.1 micrometer and define an included angle of at least sixty degrees, a radius at the ultimate tip of the strengthening material of less than 400 angstroms and an aspect ratio in the range of 1:1-3:1.

In a particular shaving unit, the razor blade structure includes two steel substrates, the wedge-shaped edges are disposed parallel to one another between the skin-engaging surfaces; a layer of interlayer material is between the steel substrate and the edge strengthening layer and is of diamond or DLC material; each layer of interlayer material has a thickness of less than about five hundred angstroms; each diamond or DLC coating has a thickness of at least about twelve hundred angstroms; substantial sp3 carbon bonding; a mass density greater than 1.5 grams/cm^3; and a Raman peak at about 1331 cm^{-1} (diamond) or about 1550 cm^{-1} (DLC); and an adherent polymer coating is on each layer of diamond or diamond-like carbon material.

The shaving unit may be of the disposable cartridge type adapted for coupling to and uncoupling from a razor handle or may be integral with a handle so that the complete razor is discarded as a unit when the blade or blades become dull. The front and rear skin-engaging surfaces cooperate with the blade edge (or edges) to define the shaving geometry. Particularly preferred shaving units are of the types shown in U.S. Patent 3,876,563 and in U.S. Patent 4,586,255.

Other features and advantages of the invention will be seen as the following description of particular embodiments progresses, in conjunction with the drawings, in which:

Fig. 1 is a perspective view of a shaving unit in accordance with the invention;

Fig. 2 is a perspective view of another shaving unit in accordance with the invention;

Fig. 3 is a diagrammatic view illustrating one example of razor blade edge geometry in accordance with the invention;

Fig. 4 is a diagrammatic view of apparatus for the practice of the invention; and

Figs. 5 and 6 are Raman spectra of DLC material deposited with the apparatus of Fig. 4.

Description of Particular Embodiments

With reference to Fig. 1, shaving unit 10 includes structure for attachment to a razor handle, and a platform member 12 molded of high-impact polystyrene that includes structure defining forward, transversely-extending skin engaging surface 14. Mounted on platform member 12 are leading blade 16 having sharpened edge 18 and following blade 20 having sharpened edge 22. Cap member 24 of molded high-impact polystyrene has structure defining skin-engaging surface 26 that is disposed rearwardly of blade edge 22, and affixed to cap member 24 is shaving aid composite 28.

The shaving unit 30 shown in Fig. 2 is of the type shown in Jacobson U.S. Patent 4,586,255 and includes molded body 32 with front portion 34 and rear portion 36. Resiliently secured in body 32 are guard member 38, leading blade unit 40 and trailing blade unit 42. Each blade unit 40, 42 includes a blade member 44 that has a sharpened edge 46. A shaving aid composite 48 is frictionally secured in a recess in rear portion 36.

A diagrammatic view of the edge region of the blades 16, 20 and 44 is shown in Fig. 3. The blade includes stainless steel body portion 50 with a wedge-shaped sharpened edge formed in a sequence of

edge forming honing operations that forms a tip portion 52 that has a radius typically less than 500 angstroms with facets 54 and 56 that diverge at an angle of about 13°. Deposited on tip 52 and facets 54, 56 is interlayer 58 of molybdenum that has a thickness of about 300 angstroms. Deposited on molybdenum interlayer 58 is outer layer 60 of diamond-like carbon (DLC) that has a thickness of about 2,000 angstroms, with facets 62, 64 that have lengths of about one-quarter micrometer each and define an included angle of about 80°, facets 62, 64 merging with main facet surfaces 66, 68 that are disposed at an included angle of about 13° and an aspect ratio (the ratio of the distance (a) from DLC tip 70 to stainless steel tip 52 and the width (b) of the DLC coating 60 at tip 52) of about 1.7. Deposited on layer 60 is an adherent telomer layer 72 that has a substantial as deposited thickness but is reduced to monolayer thickness during initial shaving.

Apparatus for processing blades of the type shown in Fig. 3 is diagrammatically illustrated in Fig. 4. That apparatus includes a DC planar magnetron sputtering system manufactured by Vac Tec Systems of Boulder, Colorado that has stainless steel chamber 74 with wall structure 80, door 82 and base structure 84 in which is formed port 86 coupled to a suitable vacuum system (not shown). Mounted in chamber 74 is carousel support 88 with upstanding support member 90 on which is disposed a stack of razor blades 92 with their sharpened edges 94 in alignment and facing outwardly from support 90. Also disposed in chamber 74 are support structure 76 for target member 96 of molybdenum (99.99% pure) and support structure 78 for target member 98 of graphite (99.999% pure). Targets 96 and 98 are vertically disposed plates, each about twelve centimeters wide

and about thirty-seven centimeters long. Support structures 76, 78 and 88 are electrically isolated from chamber 74 and electrical connections are provided to connect blade stack 92 to RF power supply 100 through switch 102 and to DC power supply 104 through switch 106; and targets 96 and 98 are connected through switches 108, 110, respectively, to DC magnetron power supply 112. Shutter structures 114 and 116 are disposed adjacent targets 96, 98, respectively, for movement between an open position and a position obscuring its adjacent target.

Carousel 88 supports the blade stack 92 with the blade edges 94 spaced about seven centimeters from the opposed target plate 96, 98 and is rotatable about a vertical axis between a first position in which blade stack 92 is in opposed alignment with molybdenum target 96 (Fig. 4) and a second position in which blade stack 92 is in opposed alignment with graphite target 98.

In a particular processing sequence, a stack of blades 92 (thirty centimeters high) is secured on support 90 (together with three polished stainless steel blade bodies disposed parallel to the target); chamber 74 is evacuated; the targets 96, 98 are cleaned by DC sputtering for five minutes; switch 102 is then closed and the blades 92 are RF cleaned in an argon environment for three minutes at a pressure of ten millitorr, an argon flow of 200 sccm and a power of 1.5 kilowatts; the argon flow is then reduced to 150 sccm at a pressure of 4.5 millitorr in chamber 74; switch 106 is closed to apply a DC bias of -50 volts on blades 92; switch 108 is closed to sputter target 96 at one kilowatt power; and shutter 114 in front of molybdenum target 96 is opened; for twenty-eight seconds to deposit a molybdenum layer 58 of about 300 angstroms thickness on the blade edges 94. Shutter 114 is then closed, switches 106 and 108

are opened, and carousel 88 is rotated 90° to juxtapose blade stack 92 with graphite target 98. Pressure in chamber 74 is reduced to two millitorr with an argon flow of 150 sccm; switch 110 is closed to sputter graphite target 98 at 500 watts; switch 102 is closed to apply a 13.56 MHz RF bias of one thousand watts (-440 volts DC self bias voltage) on blades 92, and concurrently shutter 116 is opened for twenty minutes to deposit a DLC layer 60 of about two thousand angstroms thickness on molybdenum layer 58. The DLC coating 60 had a radius at tip 70 of about 250 Angstroms that is defined by facets 62, 64 that have an included angle of about 80°, an aspect ratio of about 1.7:1, and a hardness (as measured on the planar surface of an adjacent stainless steel blade body with a Nanoindenter X instrument to a depth of five hundred angstroms) of about seventeen gigapascals (the stainless steel blade body having a hardness of about eight gigapascals). As illustrated in Fig. 5, Raman spectroscopy of the coating material 60 deposited in this process shows a broad Raman peak 120 at about 1400-1500 cm^{-1} wave number, a spectrum typical of DLC structure.

A coating 72 of polytetrafluoroethylene telomer is then applied to the DLC-coated edges of the blades. The process involves heating the blades in a neutral atmosphere of argon and providing on the cutting edges of the blades an adherent and friction-reducing polymer coating of solid PTFE. Coatings 58 and 60 were firmly adherent to the blade body 50 and provided low wet wool felt cutter force (the lowest of the first five cuts with wet wool felt (L5) being about 0.45 kilogram), and withstood repeated applications of wet wool felt cutter forces (the lowest cutter force of the 496-500 cuts being about 0.65 kilogram), indicating that the DLC coating 60 is substantially unaffected by exposure to the severe

conditions of this felt cutter test and remains firmly adhered to the blade body 50. Edge damage and delamination after ten cuts with dry wool felt as determined by microscopic assessment was substantially less than commercial chrome-platinum coated blades, there being less than four small edge damage regions (each such small damage region being of less than twenty micrometer dimension and less than ten micrometer depth) and no damage regions of larger dimension or depth. Resulting blade elements 44 were assembled in cartridge units 30 of the type shown in Fig. 2 and shaved with excellent shaving results.

In another particular processing sequence, a stack of blades 92 (thirty centimeters high) is secured on support 90 (together with three polished stainless steel blade bodies disposed parallel to the target); chamber 74 is evacuated; the targets 96, 98 are cleaned by DC sputtering for five minutes; switch 102 is then closed and the blades 92 are RF cleaned in an argon environment for two and a quarter minutes at a pressure of ten millitorr, an argon flow of 200 sccm and a power of 1.5 kilowatts; the argon flow is then reduced to 150 sccm at a pressure of six millitorr in chamber 74; switch 106 is closed to apply a DC bias of -50 volts on blades 92; shutter 114 in front of molybdenum target 96 is opened; and switch 108 is closed to sputter target 96 at one kilowatt power for thirty-two seconds to deposit a molybdenum layer 58 of about 300 angstroms thickness on the blade edges 94. Shutter 114 is then closed, switches 106 and 108 are opened, and carousel 88 is rotated 90° to juxtapose blade stack 92 with graphite target 98. Pressure in chamber 74 is reduced to two millitorr with an argon flow of 150 sccm; switch 110 is closed to sputter graphite target 98 at 500 watts; switch 102 is closed to apply a 13.56 MHz RF bias of

320 watts (-220 volts DC self bias voltage) on blades 92, and concurrently shutter 116 is opened for seven minutes to deposit a DLC layer 60 of about 900 angstroms thickness on molybdenum layer 58. The DLC coating 60 had a tip radius of about 300 Angstroms, an aspect ratio of 1.6:1, and a hardness (as measured on the planar surface of an adjacent stainless steel blade body as measured with a Nanoindenter X instrument) of about thirteen gigapascals.

A coating 72 of polytetrafluoroethylene telomer is then applied to the DLC-coated edges of the blades in accordance with the teaching of U.S. Patent No. 3,518,110. The process involved heating the blades in a neutral atmosphere of argon and providing on the cutting edges of the blades an adherent and friction-reducing polymer coating of solid PTFE. Coatings 58 and 60 were firmly adherent to the blade body 50, provided low wet wool felt cutter force (the lowest of the first five cuts with wet wool felt (L5) being about 0.6 kilogram), and withstood repeated applications of wet wool felt cutter forces (the lowest cutter force of the 496-500 cuts being about 0.76 kilogram), indicating that the DLC coating 60 is substantially unaffected by exposure to the severe conditions of this felt cutter test and remains firmly adhered to the blade body 50. Edge damage and delamination after ten cuts with dry wool felt as determined by microscopic assessment was substantially less than commercial chrome-platinum coated blades, there being less than four small edge damage regions (each such small damage region being of less than twenty micrometer dimension and less than ten micrometer depth) and no damage regions of larger dimension or depth. Resulting blade elements 44 were assembled in cartridge units 30 of the type shown in Fig. 2 and shaved with excellent shaving results.

In another processing sequence, chamber 74 is evacuated; the targets 96, 98 are cleaned by DC sputtering for five minutes; switch 102 is then closed and the blades 92 are RF cleaned in an argon environment for two and a quarter minutes at a pressure of ten millitorr, an argon flow of 200 sccm and a power of 1.5 kilowatts; the argon flow is then reduced to 150 sccm at a pressure of six millitorr in chamber 74; switch 106 is closed to apply a DC bias of -50 volts on blades 92; shutter 114 in front of molybdenum target 96 is opened; and switch 108 is closed to sputter target 96 at one kilowatt power for thirty-two seconds to deposit a molybdenum layer 58 of about 300 angstroms thickness on the blade edges 94. Shutter 114 is then closed, switches 106 and 108 are opened, and carousel 88 is rotated 90° to juxtapose blade stack 92 with graphite target 98. Pressure in chamber 74 is reduced to two millitorr with an argon flow of 150 sccm; switch 110 is closed to sputter graphite target 98 at 500 watts; switch 102 is closed to apply a 13.56 MHz RF bias of 320 watts (-220 volts DC self bias voltage) on blades 92, and concurrently shutter 116 is opened for five minutes to deposit a DLC layer 60 of about 600 angstroms thickness on molybdenum layer 58. The DLC coating 60 had a tip radius of about 400 Angstroms, an aspect ratio of 1.7:1, and a hardness (as measured on the planar surface of an adjacent stainless steel blade body as measured with a Nanoindenter X instrument) of about thirteen gigapascals. As illustrated in Fig. 6, Raman spectroscopy of the coating material 60 deposited in this process shows a broad Raman peak 122 at about 1543 cm^{-1} wave number, a spectrum typical of DLC structure.

A telomer coating 72 was applied to the blade edges with a nitrogen atmosphere. The resulting coatings 58 and 60 were firmly adherent to

the blade body 50, provided low wet wool felt cutter force (the lowest of the first five cuts with wet wool felt (L5) being about 0.6 kilogram), and withstood repeated applications of wet wool felt cutter forces (the lowest cutter force of the 496-500 cuts being about 0.76 kilogram), indicating that the DLC coating 60 is substantially unaffected by exposure to the severe conditions of this felt cutter test and remains firmly adhered to the blade body 50. Edge damage and delamination after ten cuts with dry wool felt as determined by microscopic assessment was substantially less than commercial chrome-platinum coated blades, there being less than five small edge damage regions (each such small damage region being of less than twenty micrometer dimension and less than ten micrometer depth) and no damage regions of larger dimension or depth. Resulting blade elements 44 were assembled in cartridge units 30 of the type shown in Fig. 2 and shaved with excellent shaving results.

While particular embodiments of the invention has been shown and described, various modifications will be apparent to those skilled in the art, and therefore, it is not intended that the invention be limited to the disclosed embodiments, or to details thereof, and departures may be made therefrom within the spirit and scope of the invention.

CLAIMS

1. A process for forming a razor blade comprising the steps of

providing a substrate,

forming a wedge-shaped sharpened edge on said substrate that has an included angle of less than thirty degrees and a tip radius of less than twelve hundred angstroms; and

sputter depositing a layer of diamond or diamond-like carbon on said sharpened edge while an RF bias is applied to said substrate; said layer of diamond or diamond-like carbon material having a radius at the ultimate tip of said diamond or diamond-like carbon material of less than 500 angstroms and an aspect ratio in the range of 1:1-3:1.

2. The process of claim 1, wherein said substrate is mechanically abraded to form said sharpened edge.

3. The process of claim 1 or 2, wherein said wedge-shaped sharpened edge on said substrate is formed to have an included angle of less than seventeen degrees at a distance of forty micrometers from the tip of said sharpened edge and a tip radius of less than four hundred angstroms.

4. The process of any preceding claim and further including the step of applying an adherent polymer coating on said diamond or DLC coated cutting edge.

5. The process of any preceding claim and further including the step of

depositing a layer of interlayer material on said sharpened edge; and

said layer of diamond or diamond-like carbon material is deposited on said interlayer material, said layer of interlayer material on said sharpened edge having a thickness of less than about

five hundred angstroms, and said diamond or DLC coating on said interlayer coated sharpened edge having a thickness of at least twelve thousand hundred angstroms from the tip of said sharpened edge of said substrate to a distance of forty micrometers from the tip, and an ultimate tip defined by facets that have lengths of at least about 0.1 micrometer and define an included angle of at least sixty degrees, and a radius at the ultimate tip of said diamond or diamond-like material of less than 400 angstroms.

6. The process of any preceding claim, wherein said layer of diamond or diamond-like carbon material is deposited in an argon atmosphere in an evacuated chamber in which a high purity graphite target and a shutter are located; said graphite target is energized; said RF bias is applied to said substrate; and said shutter is opened to deposit said layer of diamond or diamond-like material on said sharpened edge while said RF bias is applied to said substrate.

7. A razor blade comprising a substrate with a wedge-shaped edge defined by a sharpened tip and facets that have an included angle of less than seventeen degrees at a distance of forty micrometers from the sharpened tip, and a layer of strengthening material on said wedge-shaped edge, said layer of strengthening material being at least twice as hard as said substrate and having a thickness of at least twelve hundred angstroms from the sharpened tip of said substrate to a distance of forty micrometers from the sharpened tip, and an ultimate tip defined by facets that have lengths of at least about 0.1 micrometer and define an included angle of at least sixty degrees, an L5 wet wool felt cutter force of less than 0.8 kilogram, dry wool felt (ten cuts) edge damage of less than fifty small edge damage regions and no damage regions of larger dimension or depth, a

radius at the ultimate tip of said diamond or diamond-like material of less than 400 angstroms and an aspect ratio in the range of 1:1-3:1.

8. The razor blade of claim 7, wherein said layer of strengthening material is diamond or diamond-like carbon (DLC) material that has a hardness of at least thirteen gigapascal; substantial sp3 carbon bonding; a mass density greater than 1.5 grams/cm^3; and a Raman peak at about 1331 cm^{-1} (DLC) or about 1550 cm^{-1} (DLC); and further including an adherent polymer coating on said layer of diamond or diamond-like carbon material.

9. The razor blade of claim 7 or 8, and further including a layer of interlayer material on said wedge-shaped edge; said layer of interlayer material having a thickness of less than about five hundred angstroms.

10. The razor blade of any one of claims 7-9, wherein said substrate is steel; said wedge-shaped edge is formed by a sequence of mechanical abrading steps; and said layers of interlayer material and diamond or diamond-like carbon material are formed by sputtering.

11. A shaving unit comprising support structure that defines spaced skin-engaging surfaces, and razor blade structure of any one of claims 7-10 secured to said support structure, said coated wedge-shaped edge being disposed between said skin-engaging surfaces.

12. The shaving unit of claim 11, wherein said razor blade structure includes two substrates, and said coated wedge-shaped edges are disposed parallel to one another between said skin-engaging surfaces.

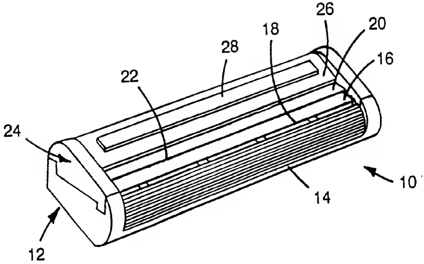


FIG. 1

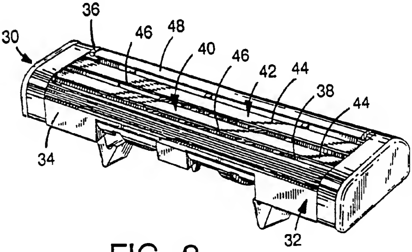


FIG. 2

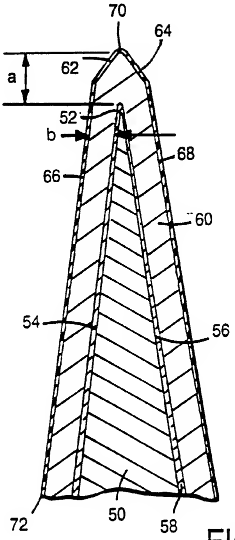

70
64
62
a
52
b
68
66
60
54
56
72
50
58

FIG. 3

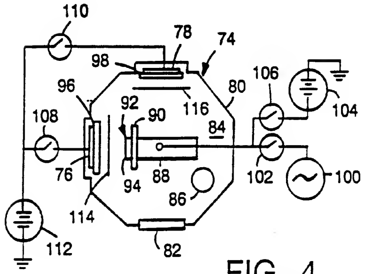

110
78
74
98
96
80
106
104
92
90
116
108
84
76
88
94
102
100
86
114
112
82

FIG. 4

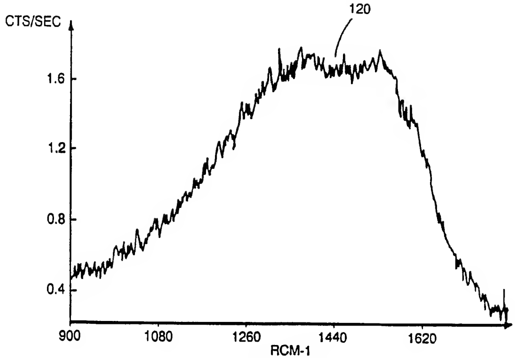

CTS/SEC
120
1.6
1.2
0.8
0.4
900
1080
1260
1440
1620
RCM-1

FIG. 5

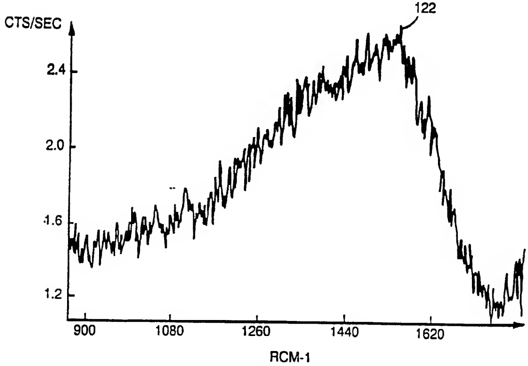

CTS/SEC
122
2.4
2.0
1.6
1.2
900
1080
1260
1440
1620
RCM-1

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/04932

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :IPC(5) B26B 21/54; C23C 14/32
US CL :U.S. CL. 30/346.54,346.55; 76/116;204/192.3
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : U.S. CL. 30/346.54, 346.55; 76/116;204/192.3, 30/50, 350; 76/104.1,Dig. 8

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A 3,761,372 (Sastri) 25 September 1973, see column 1, lines 27-30 and lines 50-53	1-6, and 9
Y	US,A, 3,829,969 (Fischbein et al.). 20 August 1974, see column 2, lines 30-47	5
Y	US,A, 4,586,255 (Jacobson) 06 May 1986, see Figure 3	11 and 12
Y	US,A, 4,720,918 (Curry et al.) 26 January 1988, see column 1, lines 8-18 and 46-54; column 3, lines 28-30	3 and 7-12
Y	US,A, 4,933,058 (Bache et al) 12 June 1990, see column 1, line 10 and 49-52; column 2, lines 35-39,54-56 and 65-68; column 3, lines 25-27; column 4, lines 10-17 and 59-60; column 5, lines 27-28, 37-41 and 57-59; column 6, lines 14-15	1-12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 JULY 1992	21 OCT 1992

Name and mailing address of the ISA/	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	HWEI-SIU PAYER
Facsimile No. NOT APPLICABLE	Telephone No. (703) 308-1405

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/04932

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [x] Claims Nos.: 4-6 and 10-12
because they relate to subject matter not required to be searched by this Authority, namely:
The claims do not comply with PCT Rule 6.4(a) because multiple dependent claims should not serve as a basis for any other multiple dependent claim.

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any addtional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention frist mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.